

CHAPTER 24

Radioactive Isotopes

In the previous chapter, stable isotopes, such as the isotopes of hydrogen and oxygen found in natural waters were discussed. These isotopes are used to identify where recharge occurs and generally the flow paths for ground water. This chapter will discuss unstable (radioactive) isotopes and how these can be used to age-date water.

The idea of radioactivity typically scares people. Some people conjure up visions of Three Mile Island or Chernobyl, but most radioactivity occurs naturally in the world and has many uses to humans other than energy generation. One may be surprised how much radioactivity is around us everyday, although the energy levels typically are quite small.

In the previous chapter, the make-up of atoms and how isotopes result from extra neutrons in the atoms was discussed. The number of neutrons in each atom was stable in that it did not change over time. Radioactivity is a little different in that the number of protons and neutrons in an atom continue to change spontaneously until a stable atom is formed. The change in protons and neutrons results in the emission of alpha and beta particles and gamma rays, all of which give radioactivity its dangerous reputation. The alpha, beta, and gamma emissions are what result in human health issues because, in sufficient quantities, they can cause cell damage in the body.

Federal and State agencies monitor and regulate radioactivity in drinking water using established levels for uranium, radium, and gross alpha and beta particles below which it is considered safe to consume. These typically are extremely low levels and most locations in the country meet the standards. Radon may be an exception in Nevada where many ground-water samples show levels exceeding the proposed maximum contaminant level.

An important radioactive isotope for hydrologists is tritium. Tritium is hydrogen with two neutrons (remember deuterium is hydrogen with one neutron). Tritium in low concentrations occurs naturally and is formed by cosmic rays interacting with atoms in the upper atmosphere.

However, nuclear weapons testing in the 1950s and 1960s added much tritium to the atmosphere. Large spikes in the tritium concentrations that occur in the environment relate to specific time periods when large and multiple nuclear weapons tests took place. This is



Soil-water vapor sampling for determination of tritium in the deep unsaturated zone at borehole UZB-2, Amargosa Desert Research Site.

very evident when looking at ice cores from Antarctica and Greenland, where annual snow accumulation provides an atmospheric and climatic record for thousands of years before present. In these ice cores, large spikes in the beta activity occur in the ice layers deposited in the 1950s and early 1960s. By this same principle, if one tests for tritium in ground water, tritium levels can relate to dates of precipitation, and therefore used to estimate when the water was recharged (the age of the water). This works for water that entered the ground after 1953.

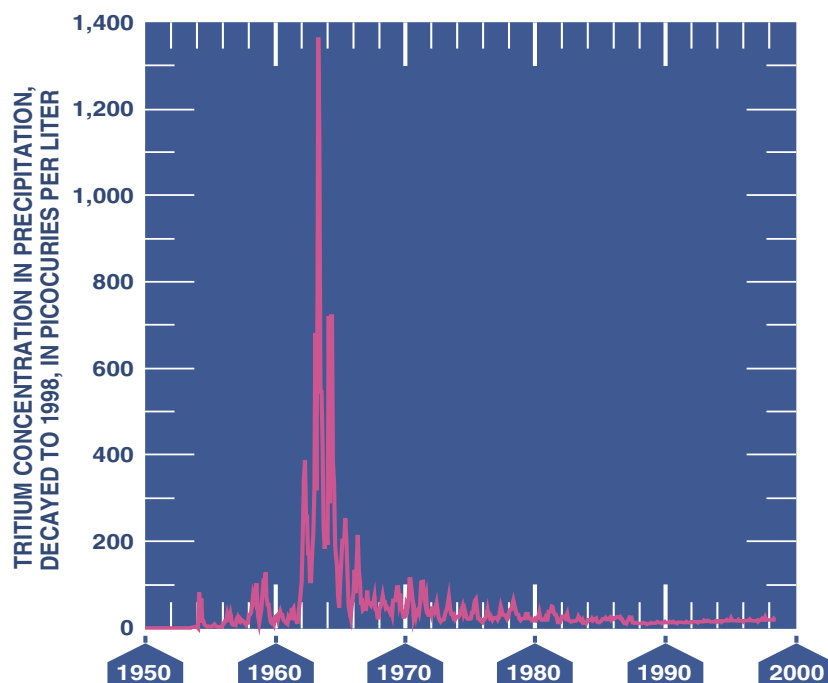
Because tritium is radioactive, its concentration is constantly changing and decreases in concentration by half every 12.4 years (this is known as the radioactive half-life for tritium). Above-ground nuclear weapons testing ceased decades ago and tritium levels are now approaching natural background levels, so scientists will not be able to use tritium alone to age date water for much longer.

Another important isotope is carbon-14. Carbon-14 occurs naturally in carbon dioxide. The carbon-14 in the atmosphere is taken up by plants and animals, as well as deposited in some rocks as they form. Once the carbon-14 is isolated from the atmosphere, it begins to decay into carbon-12 (the typical atom of carbon). The half-life of carbon-14 is 5,570 years. Therefore, by looking at the ratio of carbon-14 to carbon-12 in a buried plant or animal remains, the date of death can be estimated, or in rocks, the date of formation. This is a common practice for dating wood and animal remains from the last ice age.

This also works for water. When ground water is recharged, it contains levels of carbon dioxide. By looking at the ratio of carbon-14 to the resultant carbon-12, the age of the recharge can be estimated. Ground water has been dated using carbon-14 to dates from 50,000 to 80,000 years before present. This kind of information is important in determining how long ago water was recharged into an aquifer and the rate of flow within an aquifer.

Other types of radio-active isotopes are used by hydrologists. Chlorine-36 has a half-life of 300,000 years, so it can be used to date very old water. Tritium and iodine-129, as well as other isotopes, are used to identify and track contamination of ground water by nuclear waste.

Therefore, because the rate of decay in radioactive isotopes is known, it can be used as a tool to age-date ground water. However, this provides only part of the story. In addition to determining ages, aquifer tests, models, and other tools are needed for obtaining an overall conceptual picture of the hydrology for a region. Stable and radioactive isotopes provide an important part of this process.



Source: Cordy, G.E., Gellenbeck, D.J., Gebler, J.B., Anning, D.W., Coes, A.L., Edmonds, R.J., Rees, J.A.H., and Sanger, H.W., 2000, Water quality in the central Arizona basins, Arizona, 1995–98: U.S. Geological Survey Circular 1213, 38 p., online at <<http://pubs.water.usgs.gov/circ1213/>>.